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Memorandum

To: Patrick Bayou Joint Defense Group

From: David Keith and David Haury, Anchor Environmental, L.L.C.

Date: May 21, 2007

Re: Risk Assessment Approach for Patrick Bayou Superfund Site

INTRODUCTION

This technical memorandum outlines a proposed path forward for the ecological risk analysis component of the Remedial Investigation/Feasibility Study (RI/FS) of the Patrick Bayou Superfund Site, Deer Park, Texas. The memorandum is provided as an introduction to topics that are planned for discussion at our meeting in Austin, Texas, scheduled for May 30, 2007. The thoughts and ideas presented below are a work-in-progress, which we look forward to cooperatively completing with the Patrick Bayou Joint Defense Group (JDG), U.S. Environmental Protection Agency (USEPA), Texas Commission on Environmental Quality (TCEQ), National Oceanic and Atmospheric Administration (NOAA), and the other trustees and stakeholders as we move forward in the RI/FS for Patrick Bayou.

PRELIMINARY REMEDIAL ACTION OBJECTIVES

The following provides a discussion of the site Preliminary Remedial Action Objectives (PRAOs) as presented in the Preliminary Site Characterization Report (Anchor 2006). The development of these objectives involved the use of existing studies and evaluations of Patrick Bayou as the basis of information in a pre-RI/FS decision making effort known as a Decision Consequence Analysis (DCA). This DCA process included JDG, stakeholder, and agency representative participation as part of a Patrick Bayou DCA Working Group. This Group and the DCA process evaluated the current conditions of the Bayou, controllable and uncontrollable stresses to the Bayou, current and future uses of the Bayou, and attempted to identify the long-term goals for improving the functions the Site (e.g., industrial and municipal discharge watercourse, ecological habitat). Part of the process focused on achieving consensus among the stakeholders in defining the Site objectives for the remediation of the Bayou, and those

objectives are now carried forward as the PRAOs for the RI/FS. Those objectives include the following:

- Primary Objective
 - Prevent adverse effects on wildlife species that may feed at the site and prevent measurable degradation of downstream ecosystems as a result of the transport of contaminated sediment from Patrick Bayou.
- Secondary Objectives
 - Achieve measurable improvements in total ecological system functions
 - Maintain remedy flexibility in response to remedy monitoring data
 - Minimize long-term human interaction needed to maintain the remedied system

The primary PRAO focuses on managing controllable ecological disruptions in Patrick Bayou. The beneficial uses of the Bayou as defined by TCEQ include industrial discharge and navigation; however, it is also recognized that the Bayou provides ecological habitat and benefit to a variety of receptors (e.g., benthos, fish, birds, and small mammals). The physical conditions of the Bayou, including natural variations in stream bed configuration and substrate, hydraulic gradient, salinity, grain size, and the Bayou's land uses will prevent restoration of the Site to a uniform measure of ecological function. Because of these limitations, the ultimate focus of the RI/FS is to develop a strategy for producing beneficial changes by identifying and managing the controllable stressors on the bayou ecosystem.

The secondary PRAOs focus on ensuring a positive rate of improvement in regards to system function and lowering of ecological and human health risks through an efficient process. Efficiency is measured based on time, area, money, and overall effort in both the investigation and remediation of the Site.

It is the intent of the JDG to achieve this efficiency by using an adaptive management approach. Adaptive management integrates site evaluation and assessment, remedial design, management, and monitoring into a systematic approach where assumptions are developed, tested, and evaluated in order to adapt and learn as the project progresses. This approach is described by USEPA in its recent sediment guidance document (USEPA 2005). Key components of this approach are outlined below:

- The adaptive management approach tests assumptions by developing and implementing different actions in a step-wise fashion to achieve a desired outcome.
- The adaptive management approach involves taking action to improve the course of the project based on the results of previous and ongoing testing and monitoring. It may involve changing assumptions and developing interventions to respond to the new information obtained through monitoring efforts.
- The approach stresses the importance of learning by documenting the process so that the project team can evaluate the results achieved to date. This documentation enables stakeholders in the process to understand what has been attempted and learned as the project progresses, and it provides a forum to obtain and consider feedback from all involved.

The key advantage of the adaptive management approach on complex sites that have many variables, such as Patrick Bayou, is that it allows flexibility in the process of developing both remedial investigation/risk assessment data and remedial design information. This flexibility, through the use of an iterative and efficient approach, ultimately reduces uncertainties, shortens schedules, reduces overall costs, and yields more valuable information. The existing information for the Site and the PRAOs identified in the DCA process provide an excellent starting point for this type of approach.

PROPOSED RISK APPROACH

Based on a review of historical data, recent RI/FS-related field observations and associated data analysis, and experience at other similar Superfund sites, there are sediment-based sources of constituents of potential concern (COPCs) in Patrick Bayou. It is also possible that there are complete exposure pathways from these sediments to benthic organisms and other aquatic-dependent wildlife that exists in Patrick Bayou environs. Based on these findings and our ongoing discussions, there appears to be an evolving consensus between the JDG and USEPA that there is an opportunity to transition away from a traditional RI/FS process for Patrick Bayou, which would include the completion of a Baseline Ecological Risk Assessment (BERA) and Human Health Risk Assessment (HHRA), to a more direct remedy-driven process.

Because Patrick Bayou is not overly complex in terms of the spatial extent of chemical contamination or the distribution of various habitat types, it can be argued that a screening-level risk assessment is sufficient to evaluate the need for, and the effectiveness of, various remedial alternatives. However, a risk analysis at this level does not provide information required for addressing uncertainties associated with bioaccumulative pathways, or for the evaluation of the effectiveness of different risk management approaches. Moreover, because Patrick Bayou also is impacted by other non-chemical anthropogenic and natural stressors (e.g., limited habitat, ammonia) that will limit the degree to which the system will recover post-remedy, there is a need to understand how these other stressors also impact ecological receptors in Patrick Bayou. A screening-level assessment generally does not readily lend itself to this type of comparative assessment.

In a more traditional Superfund process, the results of a BERA and HHRA are used to establish current or baseline incremental risks to human health and the environment. Results from those evaluations are then used to evaluate the need for risk-based remedial actions, and the degree to which any remedial actions can reduce incremental risks to human health and the environment. Our proposed approach includes the following components:

- Leverage the large amount of existing data that exists for Patrick Bayou, and supplement those data as required
- Develop the level of detail required to adequately characterize potential incremental risks associated with each COPC
- Develop a rigorous tool that can be used to quantitatively determine the current level of risks, and evaluate the degree of risk reduction afforded by various remedial approaches
- Evaluate different remedial approaches during a focused evaluation of remedial alternatives, or Focused Feasibility Study (FFS)

The following sections provide a brief introduction to our proposed approach and present the risk analysis and management framework used in the Calcasieu Estuary as an example of the type of approach proposed for Patrick Bayou.

RISK TRANSFER APPROACH

Any risk-based metric that is developed as part of a FFS approach needs to consider exposure pathways and potential incremental risks that are associated with those pathways. The challenge is to develop an approach that effectively evaluates potential risks in a timely manner in lieu of completing a comprehensive BERA/HHRA for the Site. The approach needs to include developing a set of metrics that can be used to evaluate levels of risks and the effectiveness of various remedial alternatives that are more comprehensive and Site-specific than typical default screening-level metrics. Whatever metric is developed should provide adequate information to conduct cost/benefit analyses for various remedial alternatives, and also provide the regulatory community with the information it needs to ensure that proposed remedial activities are ultimately protective of human health and the environment.

To overcome the limitations inherent in a screening-level approach, and to avoid a lengthy and somewhat redundant set of analyses for a site-specific baseline risk assessment, we are recommending the use of a Risk Transfer approach, which makes use of relationships identified from similar settings between COPCs and ecosystem responses. The proposed Risk Transfer approach would use both deterministic and probabilistic risk assessment approaches developed and successfully utilized at other similar sites along the Gulf Coast to efficiently and effectively complete a risk assessment model for Patrick Bayou.

The overall objective of the Risk Transfer approach is to use technical risk assessment methodologies and site-specific analyses employed at other similar sites in a streamlined risk assessment for Patrick Bayou. The approach will make full use of available Patrick Bayou site-specific data and is more detailed than a simple screening-level risk assessment, which tends to default to a comparison of bulk sediment concentrations to published sediment quality guidelines (SQGs). Details normally developed in a BERA, including exhaustive surveys of receptors, exposure pathways, area use factors (AUF), and bioaccumulation factors are available from experience at other similar sites. Utilizing these sources of information will help the agencies and the JDG to develop a solution to the current risks in a quicker timeframe, and still provide the required regulatory assurances that risks and exposure pathways are adequately characterized and addressed.

The proposed Risk Transfer approach would focus primarily on the assessment of incremental ecological risks; however, a streamlined approach for assessing potential risks and exposure pathways to human health also will be developed. The primary sites that we believe are similar in nature with regard to contaminants, media, and exposure pathways to Patrick Bayou, and that can be used to transfer risk assessment approaches and results to Patrick Bayou are Calcasieu Estuary (Lake Charles, Louisiana), Lavaca Bay (Point Comfort, Texas), Greens Bayou (Harris County, Texas), and the Houston Ship Channel/Galveston Bay (Harris County, Texas).

The Risk Transfer approach assumes that, while the overall level of ecological and human use services provided by these other sites relative to Patrick Bayou may be measurably different, there are many important similarities:

- The other sites are contaminated sediment sites
- Classes of contaminants of potential concern are the same
- Exposure pathways are similar
- Classes of receptors of concern are the same

For example, although many of the bayou, shoreline, mudflat, and marsh habitats within Patrick Bayou differ from similar habitats within the Calcasieu Estuary Study Area because of permitted human activities, exposure to sediment-based bioaccumulative compounds such as mercury, polychlorinated biphenyls (PCBs), and dioxins/furans by piscivorous birds is of concern in both systems. Similarly, other classes of receptors may be exposed as well (e.g., sediment-probing birds and benthic invertebrates).

Technical risk assessment approaches utilized in the Calcasieu Estuary Study Area and at other sites can be transferred to Patrick Bayou to estimate potential incremental risks associated with exposure to sediment-based COPCs that are the same in both systems. However, the overall spatial extent and ecological severity of potential risks, in terms of impacts at the population or community level, needs to be adjusted to account for differences, if any, in the overall level of ecological activity within Patrick Bayou compared to a site such as the Calcasieu Estuary Study Area. This adjustment can be done in a straightforward manner, using metrics such as AUFs and habitat suitability studies.

There are, of course, many levels of uncertainty associated with the evaluation of ecological and human health risks at complex contaminated sediment sites. Uncertainty arises because of a lack of precise understanding of the movement of sediment-based COPCs into trophic food webs and resultant exposure to these COPCs by ecological and human receptors through their diet. There is also uncertainty associated with the degree to which sediment-based chemical stressors adversely impact the overall health of the benthic community, given the myriad of natural stressors that impact the benthic community in complex aquatic systems.

A screening level risk assessment will not be able to account for these uncertainties because it is a deterministic approach that compares an exposure point concentration to a generic risk-based threshold, and does not consider how exposure point concentrations and other relevant variables that affect risk may vary over space and time. A more detailed site-specific baseline risk assessment approach relies on site-specific data to reduce some of these uncertainties, but this process is lengthy and delays remedial actions, and will not remove all of the uncertainty associated with understanding complex environmental systems. A Risk Transfer approach, however, can be developed as a probabilistic approach, where uncertainty can be explicitly incorporated, and valuable information developed at similar sites can be incorporated to help reduce uncertainty at a level that is significantly more detailed and flexible than that used in screening level assessments, but in a timeframe far less than that of a site-specific baseline risk assessment. The following section discusses the risk assessment and risk management approaches utilized in the Calcasieu Estuary Study Area. The approaches used at this site provide the primary basis for the proposed approach at Patrick Bayou.

CASE STUDY: CALCASIEU ESTUARY RISK ASSESSMENT AND MANAGEMENT APPROACH

The following discussion provides a brief overview of the remedial approach being implemented at Bayou d'Inde in Lake Charles, Louisiana, which is part of the larger Calcasieu Estuary Study Area Remedial Investigation. There are two important components of this approach that are relevant to the proposed approach for Patrick Bayou: 1) the BERA methodologies developed and implemented by USEPA at this site; and 2) the risk management methodologies developed subsequently to evaluate remedial alternatives in a risk-based context.

The USEPA BERA evaluated potential incremental risks associated with a comprehensive list of COPCs, exposure pathways, and receptor groups. Based on the results of the BERA, the subsequent risk management framework developed to evaluate the effectiveness of a number of potential remedial approaches focused on the following receptor groups, pathways, and primary COPCs:

- Receptor Group – Aquatic Organisms
 - Exposure Pathway – Sediments
 - Primary COPCs – includes metals, polycyclic aromatic hydrocarbons (PAHs), and PCBs
- Receptor Group – Aquatic-dependent Wildlife
 - Exposure Pathway – Ingestion of fish and invertebrates (seven classes of fish prey and four classes of invertebrate prey)
 - Primary COPCs
 - Piscivorous Birds – mercury and dioxins
 - Piscivorous Mammals – PCBs

Because sediments are the primary source of COPC in Bayou d'Inde, the risk management approach that was developed is sediment-focused. It is a process-based approach that reduces estimated incremental risks to the receptor groups described above. The theory is that sediments are the primary accumulation point and exposure pathway for the Aquatic Organisms receptor group in Bayou d'Inde, and are a potential source of mercury, TCDD-TEQs, and PCBs in prey items consumed by Aquatic-dependent Wildlife in Bayou d'Inde. Therefore, as discussed in the following subsections, incremental risks to any of these receptor groups can be reduced through the implementation of sediment-based response actions.

Bayou d'Inde Aquatic Organisms Receptor Group

The Aquatic Organisms receptor group at Bayou d'Inde comprises the following receptor classes: benthic invertebrates, aquatic plants, microbes, and benthic and pelagic fish.

Potential incremental risks are driven by direct exposure to sediment-based COPCs.

Although a number of lines of evidence were evaluated for this diverse receptor group,

ultimately the primary measures of potential risks to the Aquatic Organisms receptor group were the results of site-specific sediment toxicity tests on benthic invertebrates.

Because effects on benthic invertebrates are likely to result from simultaneous exposure to multiple sediment-associated COPCs and other stressors, the use of numerical SQGs to predict the expected magnitude or extent of adverse biological effects of sediment-associated COPCs to aquatic receptors may be limited. Models have been developed to assess the effects of both individual COPCs and the combined effects of chemical mixtures. These models use numerical relationships between sediment chemistry and sediment toxicity to predict the concentrations of contaminants that correspond with a threshold or probable effect to benthic organisms.

To measure the effect of chemical mixtures, models using SQGs in combination have been developed to evaluate the effect of COPCs in sediment, including the Calcasieu Estuary (MacDonald et al. 2002). In the case of the Calcasieu Estuary RI/FS, the SQG was the probable effects concentration (PEC; MacDonald et al. 2000). In this model, mean PEC quotients (PEC-Q) were derived as the average of the ratios between the chemical concentrations in the samples and their respective PECs. A site-specific PEC-Q effect threshold was determined using site-specific toxicity data. See the attached Figure E2-7 from Appendix E2 to the Calcasieu Estuary BERA. This figure shows the correlation between the mean PEC-Q model and site-specific toxicity tests. The mean PEC-Q model included seven metals, 13 PAHs, and PCBs. This relationship was used as the primary risk management metric for the Aquatic Organisms receptor group. Risks to the Aquatic Organisms receptor group were categorized as low, indeterminate, or high depending on the mean PEC-Q value relative to site-specific low and high risk thresholds developed using the sediment toxicity data.

USEPA has also established mixture models for benthic effects of metals (based on AVS/SEM) and PAHs (based on equilibrium partitioning). For Patrick Bayou, the usefulness of chemical mixtures models in predicting sediment toxicity would be evaluated as part of the Work Package 3, (Risk Assessment) Work Plan.

Characterization of exposure and effects for sediment-associated contaminants to aquatic receptors in Patrick Bayou will be evaluated using the chemical mixture models and other applicable approaches discussed above. Site-specific concentration-response relationships will be evaluated using the whole-sediment and porewater toxicity tests and chemical data collected for the total maximum daily load (TMDL) studies (Parsons Engineering et al. 2002 and 2004) and the recent sediment chemistry data collected as part of the RI/FS.

Bioavailability of sediment-associated COPCs will be evaluated using equilibrium partitioning, AVS/SEM, and planned porewater testing approaches. These approaches will be used to predict the likelihood and magnitude of sediment-related toxicity to Aquatic Organisms. Spatial distribution of exposure and risk throughout Patrick Bayou will also be evaluated through the use of sediment maps, generated using Inverse Distance Weighting or similar techniques.

Aquatic-dependent Wildlife Receptor Group

The Aquatic-dependent Wildlife receptor group at Bayou d'Inde comprises the following receptor classes: sediment-probing birds, carnivorous wading birds, piscivorous birds, omnivorous mammals, and piscivorous mammals. Potential incremental risks are driven primarily by dietary exposure of bioaccumulative COPCs through ingestion of contaminated prey (fish and invertebrates). Risks were evaluated by comparing total daily intake (TDI) of COPCs to dose-based toxicity reference values (TRVs). Site-specific measurements of bioaccumulative COPCs in the tissue of prey items were used in a probabilistic risk assessment (PRA) framework to model distributions of dietary intake of COPCs as part of the TDI calculation.

Monte Carlo analysis was used to sample from the relevant input variables. Risks were evaluated by calculating the probability that a TDI exceeds a dose-based TRV. See the attached Figure H3-15 from Appendix H3 to the Calcasieu Estuary BERA. This figure shows the probability that a TDI exceeds a certain value (e.g., there is a 30 percent probability that the TDI [Exposure] exceeds 0.1 mg/kg bw/d). Based on decision criteria developed by USEPA's Calcasieu Estuary risk assessment team, risks to the Aquatic-dependent Wildlife receptor group were categorized as low, indeterminate, or high depending on the probability of exceedance of a low or high TRV.

Characterization of exposure and effects for Aquatic-dependent Wildlife in Patrick Bayou will be based on implementing a PRA approach similar to the approach described above. PRA is a computational tool that can help address uncertainty in the evaluation of ecological risks. A PRA uses probability distributions (versus point-estimates) to represent the likelihood of different risk levels in a population and to characterize uncertainty in risk estimates. PRA generally can yield risk estimates that allow for a more complete characterization of variability and uncertainty, and a potentially more useful sensitivity analysis as compared to estimating sensitivities of inputs from point estimates (USEPA 2001). For example, sensitivity analysis can help evaluate the benefit of addressing uncertainty in the risk estimate with the cost in time and resources necessary to fill data gaps.

Based on work performed at similar sites, the complete pathways and sensitive receptors most likely to contribute to risk in Patrick Bayou will be established. It is expected that models developed at other sites, primarily the Calcasieu Estuary, which has similar physical and ecological characteristics, can be adapted for use in Patrick Bayou. Site-specific modifications would include using Patrick Bayou site-specific sediment and water concentrations and modeled prey tissue burdens.

Exposure and effects assessment for Aquatic dependent Wildlife will be based to a large degree on work performed for the Calcasieu Estuary RI/FS. Exposure variable probability distributions and TRVs will be adapted to the extent possible. Variables that have a large effect on risk estimates (model sensitivity) and that depend significantly on site-specific characteristics will be developed using available site-specific information (e.g., chemical distributions and AUFs).

Due to the limited availability of prey item tissue data in Patrick Bayou, exposure assessment will include the use of one or both of the following methodologies where feasible to estimate the concentrations of bioaccumulative COPCs in prey items: 1) biota-sediment accumulation factors (BSAFs) will be calculated using data from other similar sites, including the Calcasieu Estuary—these BSAFs will be used with Patrick Bayou

sediment data to estimate tissue concentrations in prey items in Patrick Bayou; and/or 2) steady-state food web models will be used to estimate concentrations of bioaccumulative hydrophobic organic compounds (i.e., pesticides, PCBs, and dioxin/furans) COPCs in prey items as described in Arnot and Gobas (2004) or other appropriate sources. These models will be developed to approximate chemical uptake and transfer through a simplified Gulf Coast estuarine food web and will be calibrated using tissue, sediment, and surface water chemistry data from the Calcasieu Estuary RI/FS (or other appropriate sites) prior to applying models to Patrick Bayou sediment and surface water chemistry data.

Risks to Aquatic-dependent Wildlife in Patrick Bayou will be evaluated using PRA methods and outputs similar to Figure H3-15 discussed above (i.e., the probability that exposure will exceed a specific TRV). Probabilistic approaches allow for the evaluation of the stressor-response relationship and provides for the quantitative assessment of uncertainty and sensitivity.

Risk Management Process

As noted above, based on the results of the BERA, the subsequent risk management framework developed to evaluate the effectiveness of a number of sediment-based potential remedial approaches in Bayou d'Inde focused on the following receptor groups/pathways/primary COC groupings: (1) aquatic organisms/sediments/mean PEC-Q; (2) piscivorous birds/diet/mercury and dioxins/furans; and (3) piscivorous mammals/diet/PCBs.

The risk management framework developed for Bayou d'Inde is a process-based approach that reduces estimated incremental risks to the receptor groups of interest through the implementation of sediment-based remedial actions. The approach is as follows:

- Step 1. Identify and visualize the distribution of mean PEC-Q values.
- Step 2. Identify subareas with the highest mean PEC-Q values and subareas where contiguous data points exhibit elevated mean PEC-Q values. Prioritize areas where the greatest overall reduction in the surface-weighted average (SWA) mean PEC-Q value could be achieved from a given amount of remediation effort. Determine the

effect on the SWA mean PEC-Q value that would result from implementing response action.

- Step 3. Evaluate the potential effect on the SWA mean PEC-Q value as a result of monitored natural recovery over time in areas with less elevated mean PEC-Q values and isolated areas with more elevated mean PEC-Q values.
- Step 4. As necessary, designate additional subareas for response action until the estimated SWA mean PEC-Q value results in an acceptable level of risk to Aquatic Organisms over the domain in question. Demonstrate that any remaining isolated areas with elevated levels would represent a small percentage of the total area and would not have a material impact on ecological functions.
- Step 5. Evaluate the degree to which actions taken to reduce mean PEC-Q values also reduce the potential exposure to mercury, dioxins, and PCBs for those prey classes that represent an important part of the diet of Aquatic-dependent Wildlife. Evaluate how this reduction in exposure translates to a reduction of potential risk to these receptor groups.
- Step 6. To the extent necessary, evaluate additional response actions that will reduce exposure and risk to Aquatic-dependent Wildlife and Human receptors to levels that provide an overall acceptable level of protection to these receptor groups.

The risk management framework recognizes that risks vary along a continuum. This approach is consistent with the way in which the mean PEC-Q metric and the PRA approach are used at other, similar sediment sites in the Gulf Coast to quantify risks to Aquatic Organisms and Aquatic-dependent Wildlife, respectively, and how these metrics are used to evaluate risk reduction. The attached Figure 5-1 from the Draft Corrective Action Study for Bayou d'Inde illustrates how risk reduction is measured in Bayou d'Inde using the risk management framework, the mean PEC-Q metric for Aquatic Organisms, and the PRA approach for Aquatic-dependent Wildlife. The figure shows how the site-wide mean PEC-Q value is reduced through a suite of sediment-based remedial actions and how these actions also reduce the mean TDI (and, by extension, risk to Aquatic-dependent Wildlife) for dioxins/furans, mercury, and PCBs. We propose to utilize a similar approach to evaluate risk management options in Patrick Bayou.

RISK ASSESSMENT AND RISK MANAGEMENT IN PATRICK BAYOU

This section provides a brief outline of the proposed Ecological Risk Analysis and Risk Management approach for Patrick Bayou. This approach will be described in detail in the Risk Assessment Work Plan, which will be developed in the coming months and submitted to the regulatory agencies for review. The proposed risk assessment approach for Patrick Bayou will follow current USEPA Superfund risk assessment guidance but, as discussed in detail in the preceding sections, will focus on leveraging existing Site data and transferring knowledge concerning pathways, receptors, bioaccumulation, AUFs, and contaminant fate and transport from other contaminated sediment sites to Patrick Bayou.

Ecological Risk Assessment

- **Problem Formulation Phase** – Problem formulation is a process for generating and evaluating preliminary hypotheses about why ecological effects have occurred, or may occur, from human activities. The problem formulation will include identifying other regional cleanup projects that can be used to refine the conceptual site model and risk assessment methods to support an ecological risk assessment for Patrick Bayou. Information from these other sites will be used to refine the site-specific conceptual model, receptors of concern, exposure pathways, and effect levels.

Refinement of the initial COPC list identified in Work Package 1 deliverable will be evaluated in the problem formulation phase to focus the evaluation of COPCs so resources can be more effectively applied to the ecological risk assessment.

Refinement of the initial COPC list may include the evaluation of dietary considerations, frequency and magnitude of detection, and co-variance with chemicals with similar fate and transport or toxicological profiles, and bioaccumulation potential (for aquatic-dependent wildlife). A detailed explanation will be provided for any COPCs that are dropped from further consideration in the risk assessment for Patrick Bayou.

- **Analysis Phase** – The analysis phase of ecological risk assessment consists of the technical evaluation of data on the potential effects and exposure of the stressor. The analysis phase is based on the conceptual model developed during problem formulation. Although this phase consists of characterization of ecological effects

and characterization of exposure, these two steps are performed interactively to develop exposure and effects profiles used in the risk characterization phase.

Characterization of ecological effects and receptor exposure will focus on the Aquatic Organisms and Aquatic-dependent Wildlife, as discussed in the preceding sections, and will draw extensively from information generated at other sites, most notably the Calcasieu Estuary.

- **Risk Characterization Phase** – The risk characterization phase evaluates the likelihood of adverse effects occurring as a result of exposure to a stressor. The stressor-response profile and the exposure profile from the analysis phase serve as input to risk estimation. The uncertainties identified during all phases of the risk assessment also are analyzed and summarized. The estimated risks are discussed by considering the types and magnitude of effects anticipated and the spatial/ temporal extent of the effects. As discussed in the preceding sections, risks to Aquatic Organisms and Aquatic-dependent Wildlife will be evaluated using sediment chemical mixture models and PRA methodologies, respectively.
- **Risk Management** – An iterative process-based approach similar to the six-step process used in Bayou d'Inde would also be appropriate for Patrick Bayou, given the similar nature of Site in terms of COPCs, exposure pathways, and receptor groups. An iterative approach that recognizes that risks vary along a continuum and that there is uncertainty in the estimation of risks to ecological receptors is an appropriate tool to use to evaluate the effectiveness of potential sediment-based remedial actions.

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List of Figures

Figure E2-7 from Appendix E2 to the Calcasieu Estuary BERA

Figure H3-15 from Appendix H3 to the Calcasieu Estuary BERA

Figure 5-1 from the Draft Corrective Action Study for Bayou d'Inde

Figure E2-7. Plot showing the relationship between the geometric mean of mean PEC-Q and the survival of freshwater amphipod, *Hyalella azteca*, in 28-d whole-sediment toxicity tests. The dashed lines represent the 95% confidence intervals.

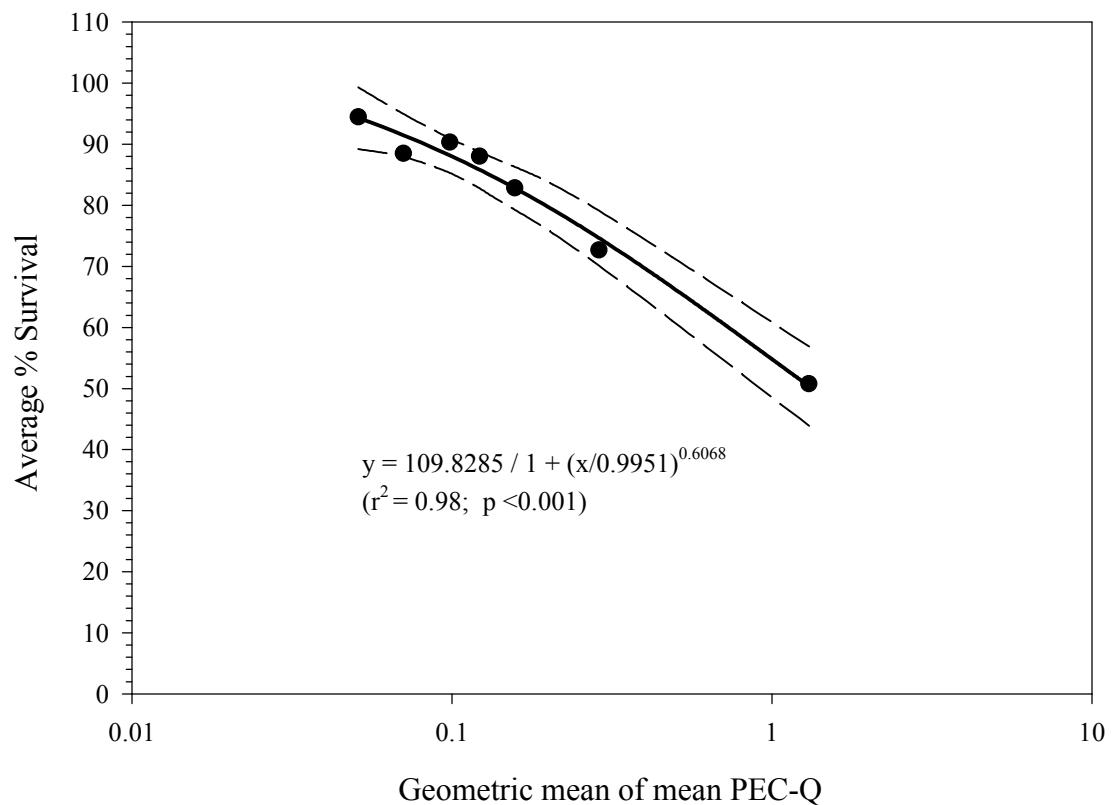


Figure H3-15. Reverse cumulative probability distribution of total daily intake rates of mercury by small piscivorus birds in Bayou d'Inde, Calcasieu Estuary.

